A self-boring pressuremeter for testing weak rock

Un pressiomètre autoforeur pour la prospection des roches meubles

B.G.CLARKE, Lecturer, University of Newcastle upon Tyne, UK
P.G.ALLAN, Research Assistant, University of Newcastle upon Tyne, UK

SYNOPSIS: A new self-boring pressuremeter has been designed to test weak rock. The instrument uses a drilling system that makes it possible to install it with minimum disturbance to the surrounding rock. It is designed to work at a pressure capacity of 20 MN/m^2 and, to enable accurate measurements to be made directly of in situ stresses and deformation moduli, thin, stiff, composite membranes and accurate displacement transducers have been developed. Successful tests have been carried out in marl and clays with compression strengths in excess of 1.5 MN/m^2 and deformation moduli in excess of 300 MN/m^2.

INTRODUCTION

Self-boring pressuremeters (SBP), developed independently in France (Baguelin et al, 1972) and in Britain (Wroth and Hughes, 1973), are increasingly being used in site investigations to obtain soil parameters for foundation design. Profiles of in situ horizontal stress and shear modulus can be determined directly from SBP field stress-strain curves. The instruments have been tried and tested in a variety of soils but their use is restricted to soils because of the drilling system and pressure capacity of the pressuremeter. A new instrument has been designed to drill into and test weak rock and details of this and examples of its use are given below.

MINIMUM DISTURBANCE DRILLING

The purpose of self boring is to achieve minimum disturbance of the surrounding material during installation of the pressuremeter. If the pressuremeter is drilled in correctly then the test can be interpretated to give directly in situ soil parameters. A typical SBP, Figure 1, includes a drill head and immediately behind, and of the same diameter, a pressuremeter. The drill head is designed so that the vertical stress across the face of the shoe is maintained and hence there are no changes in horizontal stress. The friction between the instrument and soil does affect the principal stresses but the magnitude of horizontal stress remains the same (Clarke and Wroth, 1984). The Cambridge SBP, Figure 1, uses the principle of extrusion to maintain a force balance at the base of the instrument. The cutting edge of the shoe penetrates the soil forcing the soil up into the conical shoe as the instrument advances. The pressure required to do that balances, in part, the vertical stress at the face of the shoe. The amount the shoe has to penetrate depends on the strength of the soil, the softer the soil the further the shoe has to penetrate. This technique can be used in soils with shear strengths up to 700 kN/m^2 though if the strength exceeds the effective vertical stress by a factor of three changes in horizontal stress can occur (Clarke, 1981).

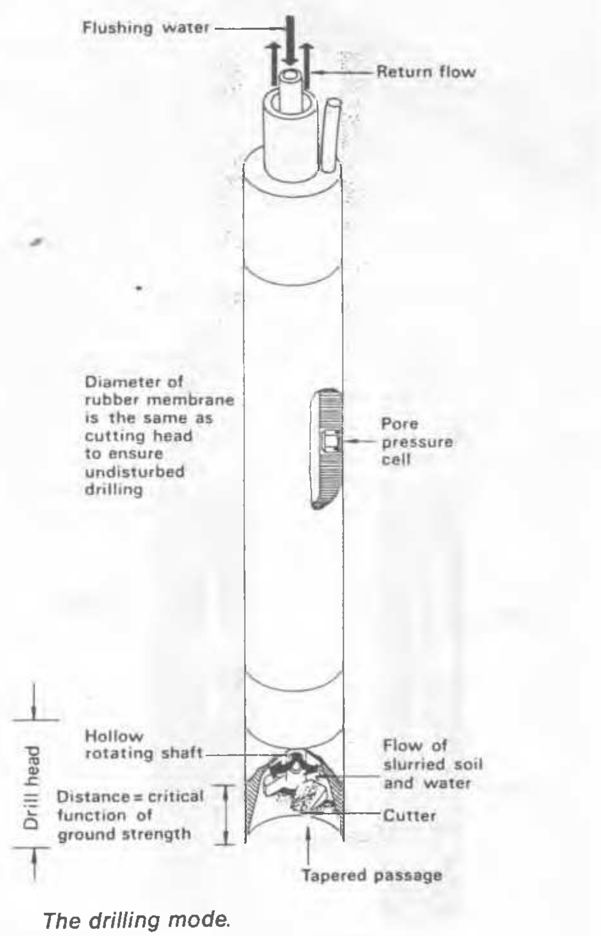

Figure 1. The Cambridge self-boring pressuremeter for use on soft ground.

The new instrument, shown in Figures 2 and 3, uses a full face cutter of the same diameter as the pressuremeter to maintain the vertical stress. The cutter is a combination bit which is accurately ground to the same diameter as the pressuremeter and just protrudes from the shoe. The diameter of the hole is maintained by a series of tunsten carbide tips mounted on the circumference of the bit. The rock within the annulus cut by those tips is cut by a series of tungsten tips set in an array radiating spirally out from the centre. Thus the face of the shoe is completely covered during one revolution of the bit. All the tips are set with a negative rake so that the material is ground away rather than chipped. This reduces overbreak. The rock particles are removed by pumping liquid polymer mud through a series of ports within the centre of the bit and back up through ports in the outer section of the bit. The bit is restrained vertically and horizontally by a bearing mounted immediately behind it within the shoe together with spiders on the inner rod driving the bit.

Figure 2. The weak rock self-boring pressuremeter.

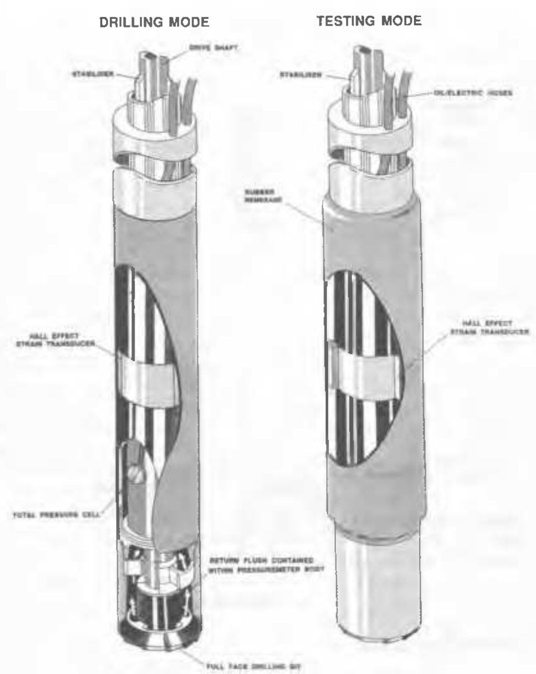

Figure 3. Details of the weak rock self-boring pressuremeter.

THE PRESSUREMETER

The new pressuremeter is 73.6mm in diameter so that it can be operated from the base of NX boreholes. The length to diameter ratio of the expanding section is five. It has a thin composite membrane designed to operate up to pressures of 20 MN/m^2. Nylon fibres running longitudinally in the outer layer of the neoprene membrane prevent the membrane stretching due to the frictional forces developed between the instrument and rock during drilling. The fibres do not resist circumferential expansion during the test. However, to prevent the neoprene being forced out through the space between the fibres when the membrane has expanded a second helical set of fibres are positioned immediately beneath the longitudinal fibres.

For safety reasons the membrane is pressurised with oil. The transformer oil is supplied to the pressuremeter through a hydraulic hose. A second hose contains an electric cable which carries the supply to and the return signals from the transducers mounted within the instrument. The two cable system allows the pressuremeter to be deaired, and more importantly, allows the pressuremeter to be used from the base of dry holes. If an instrument is lowered down a dry hole the weight of oil would cause the membrane to expand and possibly burst. In dry holes the oil is pumped down to the instrument after it has been drilled to the test location. Before the instrument is removed from its borehole the oil is forced out by blowing air down the second hose.

Three displacement transducers and a pressure transducer are mounted within the instrument together with the necessary electronics to produce a stable amplified signal. The displacement transducers are sprung loaded plates of area 50mm by 10mm. The plate tends to bridge over any possible joints in the rock. The instrument is designed so that at 20 MN/m^2 the distortion of the transducer mountings (or reference data) is negligible. The average movement of the plates is monitored with hall effect gauges.

FIELD USE

The instrument is drilled into place with a rotary rig. The pulldown rams on the rig are used to provide thrust to the bit via the instrument while the chuck is used to turn the bit. The thrust can vary between 4kN and 40kN, the difference primarily depending on the friction between the instrument and rock. The bit is turned at about 50 to 100 rpm and the speed of advance varies from 8 to 20mm/min. depending on the strength of the rock.

The procedure used to expand the membrane is similar to that used for testing soft ground. The expansion is initially stress controlled and then, beyond yield, it is strain controlled. At least one unload/reload cycle is included. The capacity of the instrument is either 10% cavity strain or 20 MN/m^2.

The transducers are calibrated against pressure gauges and micrometers in the laboratory. Membrane stiffness (or expansion in air) calibrations show that the pressure required to inflate the membrane to 10% is about 80 kN/m^2. This is insignificant when compared to the total pressure used in a test and may be ignored. Membrane compression, however, has a significant effect on deduced values of modulus. The membrane, when compressed in a confined space has a linear elastic response with an elastic modulus of 1800 MN/m^2. Calibration tests in cylinders show that the compression of the membrane is slightly greater than that exhibited in the confined test. These calibrations are repeatable and, therefore, can be applied to the field data to obtain the true stress-strain response of the rock.

TYPICAL TEST DATA

Successful tests have been carried out in coal measure mudstones and sandstones, Keuper Marl in various degrees of weathering, and clay at depths greater than two hundred metres. Figure 4 shows a calibrated stress strain curve for a test in moderately weak Keuper Marl at 18.6m below ground level. The total horizontal stress, taken directly from the curve, is 540 kN/m^2. The shear modulus evaluated from the unload/reload cycle, AB, is 840 MN/m^2. If the rock is assumed to behave as an impermeable continuum then the undrained shear strength is 4.5 MN/m^2, using the method proposed by Windle and Wroth (1977).

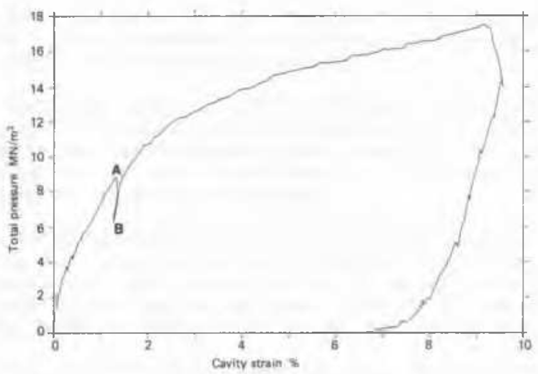

Figure 4. A test in Keuper Marl.

Figure 5 shows a calibrated stress strain curve for a test in clay at two hundred and thirty seven metres below ground level. The instrument was drilled from a gallery at a depth of two hundred and twenty three metres. The total horizontal stress, shear modulus and undrained shear strength are 303 kN/m^2, 370 MN/m^2 and 910 kN/m^2 respectively.

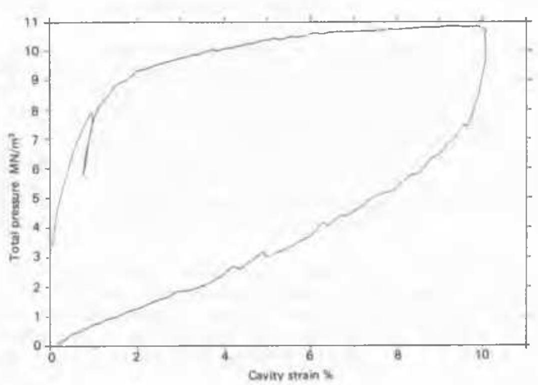

Figure 5. A test in Boom Clay.

CONCLUSIONS

A new self-boring pressuremeter has been designed for testing weak rock. It incorporates several features designed to minimise disturbance during drilling and produce the true stress strain behaviour of rock in situ from which horizontal stress, shear modulus and strength can be determined directly. Successful tests have been carried out in a variety of rocks.

ACKNOWLEDGEMENTS

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